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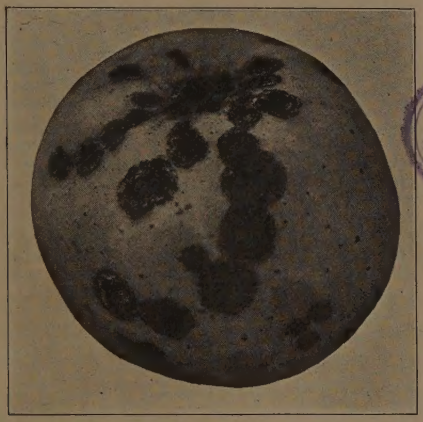

Scab infection on apple fruit. The edges of the torn cuticle are seen on the younger spots.

APPLE SCAB AND ITS CONTROL IN VIRGINIA

By

F. J. SCHNEIDERHAN AND F. D. FROMME

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APPLE SCAB AND ITS CONTROL IN VIRGINIA[1]

By F. J. Sneiderhan and F. D. Fromme

The studies of the scab disease of apple which are reported in this bulletin were carried on at Winchester, Frederick County, Virginia, during 1922 and 1923 and the facts obtained apply particularly to that locality. They may be applied, however, in a general way to all sections of the State and especially so to the Valley of Virginia. It is the plan in this bulletin to present such data as are of immediate value to the fruit grower and to omit many of the technical details of the work. These will be published at a later date.

Frederick County normally produces about one-third of the total Virginia apple crop. Apple scab has been the most important disease of this locality during recent years. It has developed since 1917 to such an extent that it is at present the chief limiting factor in the production of certain varieties of apples. Approximately one-third of all the culls in 1921 and 1922 were the result of scab infection, and losses through dropping of blossoms and young fruit, leaf injury, and poor keeping qualities have also been severe.

General Features of the Disease

Apple scab is caused by the fungous organism, *Venturia inaequalis*. It occurs generally throughout the United States and is the most important apple disease for the country as a whole, especially so in northern fruit sections. It is world-wide in occurrence, being found to some extent in all countries where apples are grown.

The apple scab pathogene has two stages, a summer stage and a winter stage. It passes the winter in infected dead leaves. Late in the fall when decomposition of the fallen scabby leaves sets in, the mycelium of the fungus, which hitherto had been superficial, invades the entire tissue of the dead leaves and begins to form fruiting bodies which are called perithecia. These bodies contain the asci or spore

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sacs in which ascospores are produced in the spring. A single perithecium with the enclosed ascospores is shown in figure 1. The formation of ascospores begins about the middle of March and the spores are mature and ready to be discharged about the middle of April under Frederick County conditions. This is approximately at the pink stage of the blossoms.

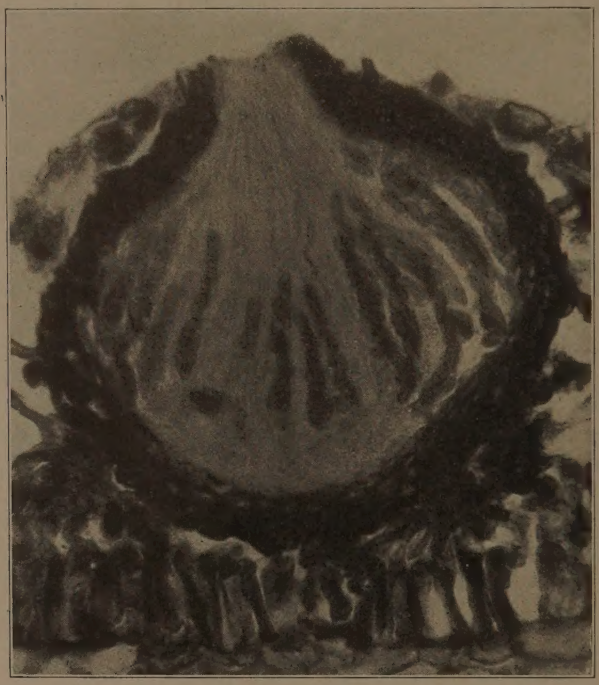

FIG. 1.—The winter stage of the scab fungus enlarged about 500 times. The perithecium is formed within the tissue of the apple leaf. The ascospores, which are two-celled, are borne within the perithecium and are discharged through the opening at the top during rainfall.

The ascospores are discharged during or immediately following rainfall. The spores are forcibly ejected into the air and are carried by wind or other agencies to the young leaves or fruits where they cause the initial infection. They are produced in prodigious numbers. It has been estimated that as many as eight billion spores may be discharged from the dead leaves under one large apple tree after an hour of rain. The spores, landing on the young leaves or blossoms germi-

nate and produce a hypha or infection thread which pierces the cuticle directly and thus causes infection. The under side of the leaves generally show the first infection because this side is most exposed in the early period following emergence. Little evidence of the disease is seen for approximately two weeks after infection when the fungus forms a very much branched and spreading mycelium which disrupts the cuticle of the leaf and produces a green olivaceous spot. The summer spores, or conidia, are produced on this spot and are pinched off successively from the tips of spore stalks. These spores are produced in very large numbers and are carried by wind or other agencies

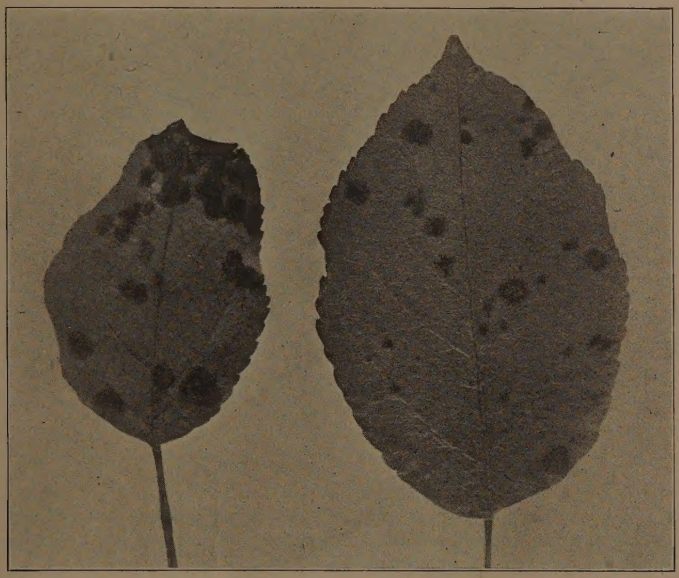

FIG. 2.—Scab spots on apple leaves. The webbed type of spot is shown on the leaf to the right.

and reinfect leaves and fruit. Depending upon moisture conditions, this process of spore production and reinfection repeats itself a number of times during the early summer months and provides for the rapid spread of the disease. Infection persists throughout the growing season on both fruit and leaves and with the death and dropping of leaves in the fall the winter or perithecial form is again developed.

The apple scab fungus attacks the leaves, blossoms and fruit of the apple tree; less commonly it also infects the twigs. It has no hosts except the cultivated apple and other species of apple.

On the leaves, the fungus appears first on the lower surface in the form of dark olivaceous spots which have a webbed appearance and an irregular outline. Later, the spots also occur on the upper surface where they are somewhat larger than those on the lower surface. Typical scab spots are shown in figure 2. The surface area of the leaf opposite the spot becomes concave while the surface directly affected becomes bulged or convex. Spots on both surfaces occur more frequently along the veins. In the case of a very heavy infection the spots unite and produce dead areas in the leaf, and this is usually followed by defoliation.

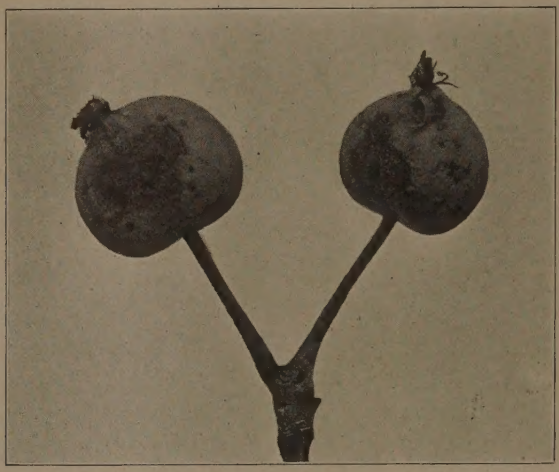

FIG. 3.—Scab spots on young apples. The large spots are the first infections from ascospores and the small spots nearby are secondary infections from conidia produced on the large spots.

The blossoms also become infected and typical greenish spots are produced on the calyx and the pedicels. The petals are not infected. Blossom infection is usually followed by dropping of the blossom or young fruit.

The scab spot on the fruit is familiar to almost every apple grower and yet it is often mistaken for other diseases, particularly cloud. The first scab spots noticeable on the fruit are usually found at the calyx end because infection occurs while the small apples are still in the upright position. The small spots on the fruit have a typical whitish margin composed of the undigested cuticle which has been disrupted by the growth of the mycelium between the cuticle and the

tissue lying beneath it. This is shown in the illustration on the cover page. In large spots on the fruit the original appearance changes so that eventually the fungal weft disappears leaving a corky layer of host tissue which is the usual adaptation of an injured tissue to prevent water loss. Finally the corky layer becomes lighter colored and gives the appearance of a russetted spot similar to the area surrounding a curculio sting. In severe scab infection of the fruit, the spots converge and cracking results. Apples with numerous spots on one side become dwarfed, lopsided and frequently drop prematurely while those with only a few spots are often noticeably deformed or dwarfed. The apples in figure 4 show the various types of injury caused by scab.

No rot of the fruit is produced by the scab fungus directly but the scab lesions are readily invaded by rot fungi, such as pink mold, blue mold, and black rot. This frequently occurs under storage conditions, also while the apples are still on the tree. There is no spread of scab infection in storage, but apples which show little or no infection at harvest may develop some scab during storage. In this case, infection has taken place prior to harvest and the disease was present but in the incubation stage at the beginning of storage.

Twig infection occurs so rarely in Virginia that a detailed description is unnecessary.

The losses from scab which are most apparent to the grower are those which result from fruit infection and which relegate to the cull pile those apples that normally would go into barrels. There are other injuries, however, that must be considered in enumerating all of the losses caused by this disease. Among these are the following:

Reduction in the size of fruit. — This is quite noteworthy and is the result of disturbed functioning of the infected leaves as well as the direct dwarfing effect of the infection on the fruit.

The dropping of infected blossoms. — This results in a smaller set of fruit than would be expected in the absence of infection of the flower parts. In a year of heavy blooming this is probably not important but in years of light bloom the infection by scab may easily be the determining factor of crop production.

Poor keeping quality of infected fruit. — Scabby fruit does not store properly because, as previously stated, the scab spots are vulnerable points for the invasion of certain rot fungi which commonly develop in storage.

Defoliation resulting from severe leaf infection. — This interrupts the complete seasonal period for food elaboration and injures the tree as a whole. Any disturbance of the normal leaf area may result in diminishing the apple crop.

All varieties of apple are subject to scab infection; some are notoriously susceptible, however, and others are relatively immune except under conditions of very severe exposure. The York Imperial, for example, is usually considered quite resistant, yet in the severe epidemic of 1922 it developed as much as 60 per cent of infected fruit. Under average conditions in Virginia, however, this variety develops but little scab and compared with such varieties as Winesap and Rome is to be considered as relatively immune. Of the varieties commonly grown in Virginia the following may be listed as susceptible: Winesap, Rome, Virginia Beauty, Lowry, Black Twig, Ben Davis, Gano, Delicious, Stayman, King David, Early Harvest; and as less susceptible: Jonathan, Duchess, Transparent, York Imperial and Grimes.

FIG. 4.—Apples in midseason showing cracking and deformity due to severe scab infection. The varieties shown are Winesap (left), Delicious (center), and Stayman.

The scab fungus is an early season, cool weather parasite which develops most rapidly under humid weather conditions. It stands in strong contrast to the fungus which causes bitter rot, the latter being a typical warm weather, late season parasite. The development of scab is arrested to a marked degree during the hot weather of midsummer. It may again become active with the return of cool weather in the fall and the late season infection is occasionally of serious importance.

Experimental Work

The investigations included studies on the discharge of scab ascospores and spraying experiments which had for their aim the de-

termination of the relative and absolute values in scab control of each spray in a fixed schedule.

Complete meteorological records were kept in order to determine the relation of such climatic factors as precipitation, temperature, and humidity, to the discharge of ascospores and to scab infection and development. The data obtained on the discharge of ascospores were used as a guide in the timing of the spray applications. The standard spray materials as outlined in the Virginia spray calendar were used, and the applications were made with power equipment such as is found in the best managed orchards. In addition to the scab studies, data were obtained on the time of first appearance of all fungous diseases and on their occurrence and severity.

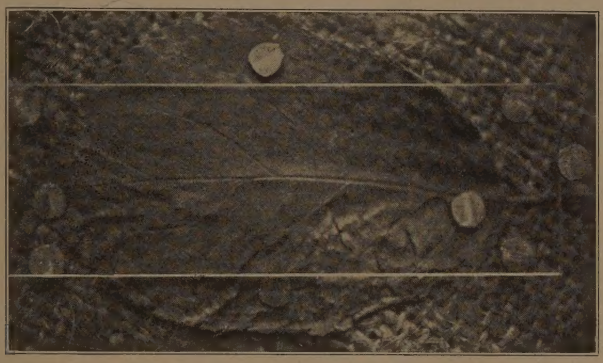

FIG. 5.—An apple leaf covered with a glass slide in position for the study of scab ascospore discharge.

THE DISCHARGE OF ASCOSPORES

For the study of ascospore discharge, leaves which had been on the ground over winter and which showed perithecia of the scab fungus were obtained in the spring and exposed to rainfall. They were fastened to the ground, as shown in figure 5, with shingle nails and the ground was covered with a single thickness of coarse gunny sacking to prevent the splashing of soil. The leaf was held to the ground with four nails and a glass microscopic slide was placed over it at a height of 3 millimeters, the thickness of a match. The slide was supported on four nails, one at each corner, and was held in position with a nail at each end, the nail head projecting over the edge of the slide and acting as a clamp. The ascospores are shot out of the perithecia during rainfall and are caught on the slides where they can be ex-

amined with a microscope. The slides were examined as soon after each rain as possible. When they were still flooded with rain water the counting of ascospores was a comparatively easy matter but when rain occurred during the night and the slides had dried by morning, counting was more difficult. The spores would be found adhering in a kind of drift where the water, draining to the lower edge, had car-

TABLE 1. — *Dates and amounts of scab ascospore discharges from apple leaves in 1922, together with rainfall for all days during the discharge period. The symbols show average number of spores per low power field of the microscope as follows: — none; x less than 10; xx 10 to 30; xxx 30 to 50; xxxx more than 50.*

Date	Rank	Leaf number										Rainfall
		1	2	3	4	5	6	7	8	9	10	
April, 18	11	—	x	x	xx	—	xx	xxx	—	—	—	.04
" 19	6	x	xxx	xxxx	xx	x	x	xx	xx	x	x	.08
" 20	15	x	—	x	—	x	—	x	x	—	—	.03
" 21	8	x	xx	x	xx	x	xx	xx	x	x	x	.20
May, 3	9	x	xx	xx	x	x	x	xx	x	x	xx	.28
" 4	16	xx	x	x	—	—	—	—	—	—	—	.18
" 5	14	x	x	—	—	—	—	x	x	x	x	.07
" 10	7	xx	x	x	xx	xx	x	x	x	xx	xx	.02
" 11	2	xxx	xxx	xxxx	xxxx	xxxx	x	x	x	xxxx	xxxx	.08
" 14	13	x	—	x	x	x	—	—	—	x	x	.06
" 17	1	xxx	xxx	xxxx	xxx	xx	xxxx	xxxx	xxxx	xxx	xx	1.43
" 18	3	xx	xxxx	xxx	xx	x	xxxx	xxxx	xxx	xx	x	.75
" 19	0	—	—	—	—	—	—	—	—	—	—	.03
" 26	4	xx	xxxx	xx	xxxx	x	xx	xxx	xxxx	xx	xx	.88
" 27	0	—	—	—	—	—	—	—	—	—	—	.09
June, 2	0	—	—	—	—	—	—	—	—	—	—	.05
" 3	5	x	xx	xx	xxx	xx	x	xx	xx	xxx	xxx	.54
" 4	10	xx	xxx	x	x	x	x	x	x	x	x	2.77
" 6	0	—	—	—	—	—	—	—	—	—	—	.05
" 11	12	x	x	x	x	—	—	x	x	x	x	.43

ried them. When such slides were reflooded with water the shrunken ascospores became distended immediately and were easily recognized among the spores of other fungi which almost invariably accompany them. Spore discharge begins commonly within ten minutes after the beginning of rainfall.

The studies of ascospore discharge in 1922 were made with 10 leaves obtained without reference to the variety of apple. In 1923

leaves of Rome, Winesap, and Stayman were used in order to determine the varietal difference, if any, in capacity for ascospore production and discharge. The leaves were numbered and ascospore discharge was recorded for the individual leaves throughout the period. The data obtained are shown in Tables 1 and 2.

TABLE 2. — *Dates and amounts of scab ascospore discharges from leaves of Stayman, Winesap, and Rome varieties in 1923, together with rainfall for all days during the discharge period. The symbols show average number of spores per low power field of the microscope as follows: — none; x less than 10; xx 10 to 30; xxx 30 to 50; xxxx more than 50.*

Date	Rank	Stayman leaves					Winesap leaves					Rome leaves					Rain-fall
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
April, 28	3	xx	xxx	xx	x	xx	x	x	xx	x	xx	x	x	x	x	xx	.83
May, 10	7	x	x	x	x	x	x	x	xx	x	x	x	x	x	x	x	.13
" 11	4	x	xx	x	xx	x	x	xx	xx	x	xx	x	x	x	xx	xx	.07
" 12	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.08
" 15	1	x	xxxx	x	xxxx	xxxx	xx	xxx	xxx	xx	xxxx	xx	xx	xxx	xxxx	xxxx	.23
" 20	2	x	xx	x	x	xxx	x	x	xxx	x	xx	x	xx	xx	xxx	xx	.61
June, 3	5	x	xx	x	x	xx	xx	x	x	x	xx	x	xx	x	x	xx	.13
" 11	8	x	x	x	x	x	[illegible]	x	x	x	x	x	x	x	x	x	.63
" 13	6	x	xx	x	x	xx	—	x	—	x	x	x	x	x	xx	x	.60
" 23	9	x	—	x	x	x	—	x	—	x	x	x	—	x	—	x	.33
" 28	10	x	—	x	x	—	—	x	—	x	x	x	—	x	—	xx	.25
July, 6	11	x	—	x	—	—	—	—	—	x	x	x	—	x	—	x	.17
" 7	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.07
" 22	12	x	—	—	—	—	—	—	—	—	x	x	—	x	—	x	.78
" 27	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.11
" 28	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.43
" 29	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.23
" 30	13	—	—	—	—	—	—	—	—	—	x	—	—	x	—	x	1.43

In 1922 there was a total of 16 ascospore discharges. The first discharge of the season occurred on April 18 and the last on June 12, a total discharge period of 56 days. The spores were discharged in greatest numbers during the middle part of May, as shown by the rank of the discharges in Table 1. All ascospore discharges were preceded or accompanied by rainfall but there was no very direct correlation between the amount of rainfall and the amount of spore discharge. The heaviest rain of the season, 2.77 inches on June 4, produced only a moderate discharge, while the very light rain of May 11, .08 inches, produced a heavy discharge. This difference is due to the fact that the rain of June 4 occurred near the end of the discharge period when the majority of the perithecia had become exhausted.

There were four days within the period of discharge when rain fell in very slight amounts with no accompanying spore discharge; these were May 19 and 27, and June 2 and 6. The amount of rainfall on these dates was not less than that which caused spore discharge on other days during the period, but the light rains of May 19 and May 27 had been immediately preceded by heavy spore discharges which had evidently exhausted the perithecia temporarily. The light rains of June 2 and June 6 came at the end of the discharge period when the perithecia were nearly exhausted and they had less effect, therefore, than rains of similar intensity in the early season. The total rainfall of the spore discharge period was 8.08 inches.

In 1923 there was a total of 13 ascospore discharges. The first discharge occurred on April 28 and the last on July 30, a total discharge period of 94 days (probably the longest period on record for the scab fungus). The total rainfall of the period was 7.11 inches. The spores were discharged in greatest numbers on May 15. Moderate discharges also occurred on several other days during the period, as shown in Table 2, but most of the discharges were slight and the total number of spores discharged during the season was much less than in 1922. There was no marked difference between the leaves of different varieties.

There were five days during the period when rain occurred without causing spore discharge. These were May 12, July 7, 27, 28 and 29. The reasons assigned for lack of spore discharge on similar days in 1922 apply to these days in 1923. There was either temporary exhaustion of the perithecia from rainfall on the preceding day or seasonal exhaustion at the end of the period. It is interesting to note that the moderately heavy rains of July 28 and 29 caused no discharge while the very heavy rain of July 30, 1.43 inches, the heaviest of the period, caused only a very slight discharge.

A comparison of the data for the two years shows clearly that the season of 1922 was much more favorable for scab infection and development than that of 1923. It has been evident in these studies and in previous ones that the early season spore discharges are more important in producing scab epidemics than those which occur later in the season. The advancing maturity of the leaves and fruit and the increase in temperature with the advance in season both play a part in this. It is probable that ascospore discharges which occur after the first of June are of little importance as a rule. In 1922 there were 13 discharges prior to June 1 and only 5 discharges prior to June 1 in 1923.

Precipitation for the months of April, May and June of the two years under discussion together with that of the six preceding years is shown in Table 3. The rainfall of May 1922 was 3.63 inches, slightly more than the eight-year average, while that of May 1923 was 1.12 inches, less than half of the average May rainfall. This is the lowest May rainfall during the eight-year period. The total rainfall for April, May and June 1923 was 5.99 inches, the lowest total for these months in the eight-year period. The average for these months is 9.67 inches.

TABLE 3. — *The eight-year average (1916-1923, inclusive) and the monthly precipitation of the ascospore discharge months, April, May and June, at Winchester, Va.*

Year	April	May	June	Total
1916	4.40	3.71	6.81	14.92
1917	2.40	2.25	2.96	7.61
1918	3.40	1.68	1.84	6.92
1919	3.10	4.24	2.74	10.08
1920	3.33	1.37	3.56	8.26
1921	3.51	6.51	3.61	13.63
1922	1.30	3.63	5.01	9.94
1923	2.93	1.12	1.94	5.99
Average	3.05	3.06	3.56	9.67

The extreme drought which persisted throughout the months of May and June and the greater part of July of 1923 not only inhibited the normal development and discharge of the ascospores of the scab fungus but such rainfall as occurred was quickly absorbed and the moisture necessary for infection following spore discharge was lacking. The water table became very low as evidenced by the drying up of many wells and an acute water shortage in the city of Winchester. A moderate rainfall was quickly absorbed and the surface soil became dry within a short time. The ideal conditions for scab infection are

found when the soil is surcharged with moisture and rainfall is followed by muggy weather with considerable moisture retained on the foliage of the trees. These conditions were not realized at any time during the critical months of 1923 while the season of 1922 showed a number of periods of ideal weather for scab infection. The wet season of 1922 was marked by a severe epidemic of scab and the dry season of 1923 by infection so slight as to be of practically no commercial importance.

The drought of 1923 was accompanied by high temperatures. The mean temperatures for the months of April, May and June were the highest recorded during the past eight years. This no doubt had an influence in checking infection by ascospores and the spread of infection by conidia, since the scab fungus develops best at cool temperatures.

The chief difference between the development of leaves and fruit during the seasons of 1922 and 1923 was found prior to the dropping of blossoms which occurred on practically the same dates during the two years. The early season development in 1922 was more advanced than that of 1923 as is shown in Table 4. The blossoms were in the pink stage on April 9 in 1922 as compared with April 19 in 1923, and in bloom on April 18, 1922 and on April 25, 1923. The calyx spray, applied at blossom drop, was made in the experimental plats on May 5 and 6 in 1922 and on May 6 and 7 in 1923. By June 1 the trees were in full foliage and the apples were one-fourth to three-eighths of full size. There were 7 ascospore discharges between the application of the pink and calyx sprays in 1922 and only one in the same period in 1923.

The first appearance of scab infection in 1922 was on May 15. It is not certain which of the preceding ascospore discharges produced this infection. The incubation period for the disease is usually about 14 days, but this may be increased with very cool weather and decreased with warm weather. The discharges of May 3, 4 and 5 were probably responsible as the previous discharges of April 18 to April 21 were followed or accompanied by unfavorable temperatures. Heavy frosts occurred on April 20, 21 and 24 and temperatures of 33, 29 and 32 degrees were registered at the laboratory on these dates; slightly lower temperatures were reported from other sections of the county. Scab infection developed vigorously during the latter half of May and throughout the month of June and by July 1 practically every fruit on unsprayed trees showed infection.

The first appearance of scab infection in 1923 was on May 16, approximately the same date as the first appearance in 1922. This

TABLE 4. — *The seasonal development of apple trees, dates of ascospore discharges, of first appearance of diseases, and of spray applications in experimental plats of two orchards in 1922 and 1923.*

Date	1922			1923		
	Seasonal development	Ascospore discharge	Sprays applied	Seasonal development	Ascospore discharge	Sprays applied
March, 25	Green-tip			Dormant		
" 29	"			"		
" 30	"		Del. Dor.	"		
April, 1	Green-tip			Green-tip		Del. Dor.
" 3	"		Del. Dor.	"		Del. Dor.
" 9	Pink			"		
" 13	"		Pink*	"		
" 18	Bloom	moderate		"		
" 19	"	heavy		Pink		
" 20	"	slight		"		
" 21	"	moderate		"		
" 23				"		Pink
" 24				"		Pink
" 25				Bloom		
" 28				"	moderate	
May, 1	Mildew			Bloom		
" 2	Petal fall			"		
" 3	"	moderate		Mildew		
" 4	"	slight		Petal fall		
" 5	"	slight	Calyx	"		
" 6	"		Calyx	"		Calyx
" 7	Frog Eye			"		Calyx
" 8				Calyx closing		
" 10	Cedar Rust	moderate		"	slight	
" 11		heavy		"	moderate	
" 14		slight				
" 15	Scab				heavy	
" 16				Scab		
" 17		heavy		Cedar Rust		
" 18		heavy		Frog Eye		
" 19			Two-weeks			
" 20					moderate	
" 23						Two-weeks
" 24			Two-weeks			Two-weeks
" 26		heavy				
June, 3		moderate			moderate	
" 4		slight				
" 6	Blotch			Blotch		
" 10			Five-weeks			
" 11		slight			slight	
" 13					slight	
" 14			Five-weeks			
" 15						Five-weeks
" 16						Five-weeks
" 23					slight	
" 28					slight	
July, 1	Black Rot and Bitter Rot					
" 6					slight	Ten-weeks
" 7				Cloud		Ten-weeks
" 13			Ten-weeks†			
" 17				Black Rot		
" 22					slight	
" 30					slight	
Aug., 2				Bitter Rot		
" 3						August
" 6	Cloud					
" 9						August
" 10	Stippen and Jonathan Spot					
" 13			August†			
" 15				Stippen and Jonathan Spot		
Sept., 5	Pink mold			Pink mold		
" 10						

*Both orchards were sprayed on the same day.

†The ten-weeks and August sprays were not applied in one orchard.

was probably caused by the ascospore discharge of April 28. Infection at this time was very slight and it was found only after a considerable search. There was but little additional primary infection throughout the remaining period of ascospore discharge and but little spread of infection by conidia. The maximum infection of fruits seen on unsprayed trees in the experimental plats at harvest was 7.6 per cent, as compared with 98.4 per cent in 1922. The great majority of unsprayed trees showed only 2 or 3 per cent of infected fruits. Leaf infection in 1923 was also very slight while that of 1922 was severe.

Spraying Experiments in 1922

The spraying experiments of 1922 were conducted in two orchards which contained scab susceptible varieties. The orchards were owned by Mr. Ray Robinson and Mr. James R. DuShane.[2] The Robinson orchard was particularly valuable for the work because it contained Winesap, Stayman, and Rome interplanted and this made it possible to secure results on three susceptible varieties from one series of spraying operations. The trees were ten years old. The DuShane orchard was planted to Stayman and the trees were fourteen years old. The land was level and the trees very uniform in size and vigor.

Power sprayers which developed from 250 to 300 pounds pressure were used in both orchards. The lime-sulfur applications were made with two guns, one being operated from the ground and one from the tower. The Bordeaux sprays were applied with two double-nozzled rods. Standard lime-sulfur was used at a concentration of 1-8 for the dormant and delayed dormant applications and at a concentration of 1-40 for the summer sulfur sprays. Home-made Bordeaux of the 4-5-50 formula was used for the five-weeks spray and, owing to a shortage of copper sulfate, a commercial Bordeaux was substituted for the two remaining sprays. Dry lead arsenate was used at the rate of four pounds in 200 gallons in all arsenical sprays, nicotine sulfate at the rate of 1½ pints in 200 gallons in the delayed dormant application, and Kayso,[3] a calcium caseinate spreader, was used in all sprays at the rate of 1 pound in 200 gallons.

Eight plats consisting of approximately 20 trees each were designated in each orchard and suitable check trees were distributed throughout the blocks included in the experimental work. The pro-

2Acknowledgement is made of the courtesy and co-operation of the fruit growers who have permitted the use of their orchards and equipment. The experimental work of the two seasons has been conducted in orchards of the following: Ray Robinson, James R. Dushane, Fred Robinson, Clay DeGrange, Bond Brothers, and in the Apple Ridge Orchard managed by O. L. Jameson.

3The Kayso was kindly furnished by the California Creameries, Inc.

gram of applications was the same for each orchard. It was planned to show the values of the different applications, which are included in the complete spray calendar, in the control of scab and of such other fungous diseases and insect pests as occurred. This was accomplished by the elimination of certain sprays as shown in Table 5. In plat 2, for example, the two-weeks spray was omitted, in plat 3 the pink and August sprays, etc. Plat 1 received all sprays and the check trees received none. The calyx spray was applied in all plats. This spray is usually considered essential in codling moth control and it did not seem desirable to omit it in any of the plats.

TABLE 5. — *Program of sprays as applied to the experimental plats in 1922. An* X *indicates that the designated spray was applied while a blank indicates that it was omitted.*

Name of spray application	Plat number							
	1	2	3	4	5	6	7	8
1. Delayed Dormant	X	X	X	X				
2. Pink	X	X			X	X		
3. Calyx	X	X	X	X	X	X	X	X
4. Two-weeks	X		X		X		X	
5. Five-weeks	X	X	X	X	X	X		X
6. Ten-weeks	X	X	X	X		X	X	X
7. August	X	X		X	X	X	X	X

The schedule of spray applications, materials used, the stage of development of the host and the dates of application were as follows:

1. Delayed dormant. Leaf tips well exposed in buds. Lime-sulfur 1-8 and nicotine. Robinson orchard March 30; DuShane April 3.
2. Pink. Blossom buds showing pink color, lime-sulfur 1-40 and lead arsenate. Both orchards April 13.
3. Calyx. Petals three-fourths fallen. Same materials as in No. 2. Robinson orchard May 6; DuShane May 5.
4. Two-weeks. Same materials as in No. 2. Robinson orchard May 24; DuShane May 19.
5. Five-weeks. A few days after maximum egg laying of first brood of codling moth. Home-made Bordeaux and lead arsenate. Robinson orchard June 14; DuShane June 10.
6. Ten-weeks. Commercial Bordeaux containing lead arsenate. Robinson orchard July 13; not applied in DuShane orchard.
7. August. One month after No. 6 with same material. Robinson orchard August 13; not applied in DuShane orchard.

Data on leaf infection were obtained on June 29 by examining 200 leaves of a representative tree in each plat for scab infection. The results are shown in terms of percentage in Table 6.

A very satisfactory control of scab on leaves was obtained with the complete spray schedule; the percentage of affected leaves in plat 1, which received all sprays ranged from 7 to 11, while that of the unsprayed or check trees ranged from 53 to 69. The number of leaves

used in obtaining the data was too small to warrant exact conclusions as to the value of the different sprays in scab control, but is is apparent from a comparison of the different plats that the pink, the calyx, and the two-weeks sprays were of greatest value.

The principal leaf injury in addition to that caused by scab was that of cedar rust. This was distributed rather generally throughout the plats in the Robinson orchard being especially severe on Rome. It occurred to only a slight extent in the DuShane orchard. The spraying was of some value in the control of this disease, especially on the less susceptible varieties, but the results were somewhat inconsistent and were not clearly evident in all cases.

TABLE 6. — *Percentages of leaves affected with scab in the experimental plats at Winchester in 1922.*

Plat number	1	2	3	4	5	6	7	8	Check
Sprays omitted	None	No. 4	No. 2, 7	No. 2, 4	No. 1, 6	No. 1, 4	No. 1, 2, 5	No. 1, 2, 4	All
Stayman, Robinson	10	23	28	41	15	19	34	54	67
Winesap, Robinson	11	24	35	43	27	27	40	61	69
Rome, Robinson	7	16	26	21	11		21	37	69
Stayman, DuShane	8	16	23	16	8	10	27	29	53

The data on fruit infection were obtained at harvest by the critical examination of all fruits from the trees included in the plats. The crop was quite light but the number of fruits available in most plats was large enough for reliable data. The total number of apples per plat averaged about 2,000. Each apple was examined for all defects including those due to spray injury and mechanical causes as well as those caused by diseases and insects. In addition to scab a small percentage of apples was affected with cedar rust, black rot and cloud. The latter was present to the extent of 75 per cent on the check trees of the DuShane orchard but was not distributed with sufficient uniformity throughout the plats to warrant conclusions as to the approximate values of the different applications. It was entirely absent from the plat which received the full program of sprays. There was no spray injury of any consequence in any of the plats. The most important insect pests were codling moth and aphis. Those fruits which showed no defects of any sort were classed as blemish free and the percentages of apples in this class together with those affected with scab, codling moth and aphis from the different plats are shown in Table 7. Data on blemish free fruits were not obtained for the Stayman variety in the Robinson orchard. The crop of this variety was graded according to commercial practice into No. 1, No. 2, and culls.

The percentages of No. 1 apples in the different plats were as follows: Plat 1, 95; 2, 85; 3, 65; 4, 40; 5, no fruit; 6, 70; 7, 35; 8, 45; check, 0; and the percentages of culls were: Plat 1, 5; 2, 9; 3, 25; 4, 33; 5, no fruit; 6, 25; 7, 45; 8, 32; check, 80.

A study of Table 7 shows that a very satisfactory control of scab was obtained in plat 1 which received the full program of sprays. The percentages of scab infected fruits ranged from 4.9 to 12.5 while those of the check trees ranged from 76 to 98.4 per cent. All apples which showed even a single spot were classed as scabby and the grading was consequently much more severe than would be followed in commercial practice. The greater part of the scab infection in plat 1 was very

TABLE 7. — *Percentages of apple fruits affected with scab, codling moth, and aphis and those free from blemishes in the experimental plats in 1922. A blank indicates no fruit.*

Plat number	1	2	3	4	5	6	7	8	Check
Sprays omitted	None	No. 4	No. 2, 7	No. 2, 4	No. 1, 6	No. 1, 4	No. 1, 2, 5	No. 1, 2, 4	All
				Scab					
Stayman, Rob.	4.9	16.5	47.4	53.4		10.5	53.0	34.1	76.0
Winesap, Rob.	7.5	23.9	54.6	75.4	10.6	14.6	60.0	77.0	97.3
Rome, Rob.	8.1	17.1	60.0	86.6	9.8		68.9	90.0	98.4
Stayman, DuS.	12.5	21.7	35.5	48.5	17.0	25.0	40.3	54.7	97.0
				Codling Moth					
Stayman, Rob.	0.5	0.6	0.0	1.2		1.0	2.2	1.2	10.0
Winesap, Rob.	0.2	0.2	1.7	2.1	0.1	0.4	0.7	4.6	6.2
Rome, Rob.	0.0	0.9	3.0	1.6	0.2		2.9	4.2	18.5
Stayman, DuS.	0.8	1.0	2.7	2.3	0.6	0.3	1.1	0.8	10.0
				Aphis					
Stayman, Rob.	0.0	0.2	0.0	2.0		18.0	33.0	18.0	8.6
Winesap, Rob.	0.7	0.9	3.5	0.0	25.8	29.7	29.0	21.0	31.1
Rome, Rob.	0.0	0.9	3.0	4.9	23.3		16.3	12.2	7.9
Stayman, DuS.	0.4	0.0	0.0	0.0	20.0	21.6	10.0	13.8	18.0
				Blemish Free					
Winesap, Rob.	87.5	72.5	42.6	18.0	63.8	60.0	31.6	18.0	1.3
Rome, Rob.	85.1	74.8	22.7	9.2	56.1		7.7	4.1	0.0
Stayman, DuS.	67.3	66.5	43.3	38.0	57.0	24.8	24.2	15.0	1.0

slight in character and only a few apples were noticeably affected. In the check plats, however, practically all of the scabby fruits were so severely affected as to render them almost worthless, even as cider apples. The character of the fruit from the checks in comparison with that of plat 1 is shown in figure 6.

A critical study of the scab data and comparisons between the different plats will enable the reader to form conclusions as to the value of the different spray applications in the control of this disease. It is not the purpose in this bulletin to go into a detailed interpretation of the data. The conclusions which are drawn are based on these

data but the details and steps by which they are reached would be more appropriate in a technical paper and will be given later in such a form. The conclusions reached are that the application made at the pink stage was the most important single spray in scab control, that the calyx application was second in importance, the two-weeks application third, and the delayed dormant application fourth. The five-weeks application gave a slight control in two of the plats and the ten-weeks and August sprays were of no value from the standpoint of scab. The approximate average values of the different sprays, based on the assumption that the control obtained with the full program of sprays was 100 per cent, are as follows: delayed dormant, 5; pink, 50; calyx, 25; two-weeks, 15; five-weeks, 5.

FIG. 6.—Apples from plats in the spraying experiments of 1922. Left—Winesap from plat 1 which received seven sprays, 7.5 per cent scabby. Center—Winesap from check plat, 97.3 per cent scabby. Right—Rome from plat 1, 8.1 per cent scabby.

It is evident that the pink, calyx, and two-weeks applications were all necessary for a satisfactory commercial control of scab under the conditions that prevailed in the Winchester section in 1922. The reason for this is seen when comparisons are made between the dates of ascospore discharge and the dates of spray application (see Table 4). A spray in order to be effective must be applied before infection has taken place, and since this occurs within a few hours after ascospore discharge, the spray application must precede ascospore discharge. The pink spray in 1922 was followed by 7 ascospore discharges, the calyx spray by 5, and the two-weeks by 3.

The delayed dormant, five-weeks, ten-weeks, and August sprays could have been omitted in scab control with but little increase in infection. They were, however, essential in the control of the insect pests and of the other diseases which occurred individually in relatively

small amounts but which were of considerable importance when taken in the aggregate. The data on blemish free fruit indicate that the complete program of sprays was necessary in the production of marketable apples of the varieties in question. There were practically no marketable apples in the checks and the percentages of marketable apples were materially reduced in all plats where one or more sprays were omitted.

Codling moth although not unusually severe in the check trees was present in sufficient numbers to make the tests of value. The maximum percentage of affected fruits was 18.5 which occurred in the Rome variety. A very satisfactory control was obtained with the complete program of sprays in all varieties. The calyx spray was the most important single application for the codling moth.

The most important insect pest of the year was aphis. The control of aphis with the delayed dormant spray which contained nicotine sulfate was very striking. This spray was applied in plats 1, 2, 3 and 4 and was omitted in plats 5, 6, 7 and 8 and in the checks. The maximum percentage of apples affected with aphis in the first group of plats was 4.9 and the general average was approximately 1.0 per cent. The maximum in plats 5 to 8, without nicotine, was 33.0, the minimum 10.0 and the general average about 20.8. This is higher than the general average of the checks which was about 16.4 per cent. Is is probable that some of the aphis affected apples in the checks dropped before harvest as the result of the severe scab injury to the fruit and foliage.

Spraying Experiments in 1923

The spray elimination work was conducted on a slightly modified plan in 1923. The varieties, Stayman, Winesap and Rome in the Ray Robinson orchard were again used, and in addition a block of Stayman in the Stonewell orchard, owned by Mr. Fred Robinson, was added. The latter had also been seriously affected with scab in 1922. The same schedule of applications was followed in the two orchards and the same materials were employed for the different sprays as in 1922 except that home-made Bordeaux of the 3-5-50 formula was used in the five-weeks, ten-weeks and August sprays. The lime-sulfur solutions were tested in the dilute form in the tank as well as in the concentrate form. The dates of spray applications in the two orchards in 1923 were as follows: (the first dates are for the Robinson orchard and the second dates for the Stonewall orchard) Delayed dormant, April 1, April 3; Pink, April 23, April 24; Calyx, May 7, May 6; two-

weeks, May 24, May 23; Five-weeks, June 16, June 15; Ten-weeks, July 6, July 7; August spray, August 3, August 9.

The program of applications in 1923 called for the elimination of a single spray of the regular calendar in each plat except plat 1 which received all sprays and the check which received none. The delayed dormant was omitted in plat 2 for example, the pink in plat 3, the calyx in plat 4, etc. These are indicated under the heading of sprays omitted in Table 8 which shows harvest data for fruit from the different plats. Leaf infection by scab was so slight that no attempt was made to record it.

TABLE 8. — *Percentages of apple fruits affected with scab, codling moth and aphis and those free from blemishes in the experimental plats in 1923. A blank indicates no fruit.*

Plat number	1	2	3	4	5	6	7	8	Check
Sprays omitted	None	Del. dorm.	Pink	Calyx	2 weeks	5 weeks	10 weeks	August	All
				Scab					
Stayman, Rob.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Winesap, Rob.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6
Rome, Rob.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Stayman, Stone.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2
				Codling Moth					
Stayman, Rob.	0.0	0.4	0.0	0.3		2.3	1.0	0.0	2.4
Winesap, Rob.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	4.3
Rome, Rob.	0.0	0.0	0.0	0.6	0.0		2.0	1.0	5.9
Stayman, Stone.	0.5	2.5	3.5	7.5	1.0	3.0	2.2	2.0	12.5
				Aphis					
Stayman, Rob.	0.0	15.0	10.0	7.3		0.0	0.0	0.0	17.8
Winesap, Rob.	0.0	13.8	10.0	13.0	0.0	0.0	0.0	0.0	25.0
Rome, Rob.	5.0	30.3	4.6	7.8	0.0		0.0	2.0	30.8
Stayman, Stone.	0.5	4.5	0.0	0.5	2.5	2.0	0.0	0.0	5.5
				Blemish Free					
Stayman, Rob.	95.0	76.0	86.0	71.9		90.5	96.0	91.0	65.7
Winesap, Rob.	96.0	60.4	89.9	81.7	97.0	97.0	97.0	91.0	59.0
Rome, Rob.	94.0	62.0	90.7	88.4	94.1		94.0	93.5	46.0
Stayman, Stone.	94.5	88.0	93.5	87.5	83.0	80.5	86.9	78.0	57.8

The extreme contrast between the seasons of 1922 and 1923 with respect to scab ascospore discharge, infection and development has been discussed previously and is well shown by comparison between Table 7 and 8. There was no scab in any of the sprayed plats in 1923 and the maximum recorded in the checks was only 7.6 per cent as compared with a maximum of 98.4 per cent in 1922. The type of infection in the checks was so slight that it would have been overlooked in a casual inspection. The fruit was not dwarfed or deformed by scab and the majority of infected apples bore only a single small scab spot. The worst apple in the lot bore only two scab spots.

The codling moth injury in the Robinson plats was less than in 1922; the maximum recorded for the checks is only 5.9 per cent. In the Stonewall orchard the check showed 12.5 per cent and plat 4 in which the calyx spray was omitted showed 7.5 per cent. The calyx was the most important single spray for codling moth. The full spray schedule gave almost complete control.

Aphis injury in the checks was slightly more severe than in 1922. The delayed dormant was the most important single application but the pink and calyx sprays without nicotine also appeared to exercise a considerable degree of control as their omission caused a noticeable increase in percentage of affected fruits over that found in plat 1 with the full program of sprays. The omission of the pink spray in 1922 likewise caused an increase in percentage of aphis injured fruit.

TABLE 9. — *Rainfall, maximum and minimum temperatures, and relative humidities on the days in 1922 and 1923 when ascospore discharges occurred. Favorable weather for infection is indicated by an asterisk.*

1922						1923					
Date	Rainfall	Temperature Max.	Temperature Min.	Humidity Max.	Humidity Min.	Date	Rainfall	Temperature Max.	Temperature Min.	Humidity Max.	Humidity Min.
4-18	.04	67	46	91	31	4-28	.83	73	62		
4-19	.08	47	41	100	45	5-10	.13	63	35	95	38
4-20	.03	55	41	58	18	5-11	.07	76	41	95	45
4-21	.20	41	33	100	42	5-15	.23	78	59	100	42
5- 3	.28	67	61	100	74*	5-20	.61	81	55	100	49
5- 4	.18	67	59	100	89*	6- 3	.13	96	66	100	42
5- 5	.07	71	55	98	63	6-11	.63	66	59	100	100*
5-10	.02	77	60	98	65	6-13	.60	63	55	100	92*
5-11	.08	88	60	88	33	6-23	.33	98	69	100	38
5-14	.06	74	52	100	42	6-28	.25	75	63	100	54
5-17	1.43	60	55	100	100*	7- 6	.17	90	64	100	45
5-18	.75	68	57	100	80*	7-22	.78	89	65	100	51
5-26	.88	86	64	100	70*	7-30	1.43	85	67	100	71*
6- 3	.54	75	59	99	60						
6- 4	2.77	87	60	100	52	The humidity data for April 28 are not available.					
6-11	.43	86	79	95	52						

The percentages of blemish free fruits in the checks was much higher than in 1922 as were also those of plat 1. The first three sprays of the schedule, the delayed dormant, pink and calyx, were of greater value in the production of blemish free fruit than the later sprays, and the delayed dormant was of more value than any other single spray.

It is unfortunate from the standpoint of the spraying experiments that the scab epidemic of 1922 could not have been duplicated in 1923 so that comparative values for the different sprays could have been obtained for the two years. The negative data from the work of 1923 are equally valuable, however, as the positive data of 1922 from another standpoint, that of determining the type of weather unfavor-

able for scab. It is doubtful whether two years of such marked contrast will occur again within a considerable period. A study of the meteorologic conditions which existed on the days of ascospore discharge in the two years, should, therefore, be of value in determining the type of weather favorable for scab infection and that which is unfavorable. These are shown in Table 9.

The most significant contrast between the two years is found in the relative humidities on the days of ascospore discharges. The maximum humidities were high in both years but they were accompanied by low minimum humidities in 1923 with the exception of three days, June 11, 13 and July 30. High humidity sustained over a period of several hours is necessary for infection, and these conditions did not obtain in 1923 except on these three dates which are indicated in the table by an asterisk. These days came relatively late in the season of scab infection when most of the leaf tissue had matured and hardened and when the fruit had passed the most susceptible period. There were five days of sustained high humidity in 1922, May 3, 4, 17, 18, 26, as shown by the relatively high minimum humidities which are indicated by asterisks. These came during the period of rapid leaf expansion and of immaturity of leaves and fruit which is the period of greatest susceptibility to scab infection.

It is evident that the conditions which are favorable for scab infection are abundant rainfall to provide for the discharge of ascospores, sustained high humidity following immediately after ascospore discharge, and the occurrence of both of these conditions during the period of greatest susceptibility which is during the month of May in the Winchester section. Unfavorable conditions are found when the discharge of ascospores is followed by a quick drying of the apple foliage and fruit and when the discharge occurs late in the season, in June or July.

The Occurrence of Apple Diseases in the Winchester Section

In order to obtain data on the occurrence and severity of apple diseases in the Winchester section a number of individual orchard surveys were made at harvest time. The fruit was inspected as it was brought to the packing house and a minimum of 200 fruits were examined in each case. The survey of 1922 included 32 commercial orchards representative of the general average of the section. All had received the average number of sprays made in the locality in that

year. Data were obtained on the York variety in 17 orchards, on Ben Davis in 10, on Stayman in 2, and on Winesap, N. W. Greening and Sheepnose in 1 orchard each.

The data of 1923 were obtained from 22 orchards, 9 of Ben Davis, 6 of Stayman, 2 of York, 2 of N. W. Greening, and 1 each of Jonathan, Winesap, and Rome.

The data for all varieties are summarized for the two years and are shown in Table 10. The column headed percentage of infested orchards shows the percentage of orchards in which the disease in question was found to occur; the maximum percentage of infection is the highest percentage found in any orchard, and the average percentage of infection is the average for all orchards.

TABLE 10. — *Occurrence of diseases on apple fruits in commercial orchards in Winchester section in 1922 and 1923.*

Disease	% infested orchards		Maximum % infection		Average % infection	
	1922	1923	1922	1923	1922	1923
Scab	100	36	86.5	9.0	30.1	0.9
Cedar Rust	97	36	9.0	1.5	3.6	0.3
Black Rot	91	4	13.3	5.5	3.2	0.2
Cloud	28	31	54.0	20.5	4.3	2.0
Bitter Rot	12	0	2.1	0.0	0.1	0.0
Stippen*	72	31	25.0	7.3	3.4	0.9

*Also called York Spot. A non-parasitic disease.

Blotch (Phyllosticta) was found in 3 orchards in 1922 and in none in 1923. It occurred to a very slight extent on York and on Sheepnose and was found to the extent of 100 per cent infection on a few trees of N. W. Greening. It is not an important disease in the Winchester section.

In addition to the orchard surveys a study of cull apples was made at the vinegar plants during both seasons. Samples were obtained from as many different wagon loads and of as many varieties as possible and approximately 10,000 apples were examined in each year. Assistance in collecting the data, which covers both diseases and insects as well as spray burn, climatic injuries, and mechanical injuries, was rendered by W. S. Hough, Assistant Entomologist of this Experiment Station. Many of the fruits were affected with more than one type of injury and each of these was recorded separately for each fruit. The percentages which are recorded in Table 11 represent the total occurrence of each type of injury and the combined totals may, therefore, readily exceed 100 per cent.

It is evident from the data obtained in the cull pile surveys that the injuries from fungous diseases (scab, cedar rust, black rot, cloud, and bitter rot) exceeded those caused by insects (aphis, codling moth, curculio, scale, and leaf roller) in 1922 and that the reverse was true in 1923. The disease injuries, without exception, showed a decrease in 1923, the decrease in scab injury being especially noteworthy, and the insect injuries, without exception, showed an increase in 1923, the most noticeable increases being made by codling moth and scale. It seems that the relatively wet season of 1922 was favorable for the development of fungous diseases and unfavorable for insect pests, and that the dry season of 1923 was favorable for insects and unfavorable for diseases.

TABLE 11. — *Occurrence of injuries due to various causes as found in cull apples at Winchester in 1922 and 1923.*

Cause of injury	1922		1923	
	Rank	Percentage	Percentage	Rank
Scab	1	30.9	2.3	11
Stippen	2	10.9	13.0	3
Aphis	3	9.7	11.0	5
Cloud	4	8.5	5.7	8
Cedar Rust	5	8.0	0.2	14
Codling Moth	6	7.9	20.4	1
Black Rot	7	6.4	0.5	13
Scale	8	4.0	13.0	4
Spray Injury	9	3.7	2.0	12
Undersized	10	3.2	15.6	2
Curculio	11	3.2	7.1	7
Mechanical	12	2.6	4.1	9
Leaf Roller	13	0.9	2.4	10
Bitter Rot	14	0.1	0.0	15
Drought	15	0.0	8.3	6

The data from both surveys indicate that the fruit growers in general do not secure adequate control of diseases and insects. It is estimated that approximately 50 per cent of the total tree crop of the Winchester section went into the cull pile in 1922, and approximately 40 per cent in 1923. The greater part of the injury which produced culls in both years was due to diseases and insects and was preventable by thorough and timely spraying as shown by the results obtained with the full program of sprays in the spraying experiments. An inquiry into the status of spraying practice and equipment in 1922 indicated clearly that the fruit grower in general is under-equipped for thorough spraying of the orchard within the time limits necessary for effective control. In consequence, the spraying is prolonged beyond the critical period or is rushed through at a sacrifice to thoroughness. Unsatisfactory results are likely to follow in either case. The ideal

ratio between equipment and acreage is one good 200 gallon sprayer to not more than 35 to 40 acres of bearing orchard. This ideal is far from realization in the average Virginia orchard and it is evident that a marked reduction in the existing ratio of equipment to acreage must be made before a material reduction in losses from diseases and insects can be obtained. Another factor that was responsible for the unsatisfactory control of diseases and insects in 1922 was the general failure to apply a sufficient number of sprays. This is correlated in part with under-equipment; the overworked spray outfit is apt to be laid up for repairs during a considerable part of the spraying season. Some of the growers, failing to appreciate the importance of the complete spray program, eliminated certain applications in the belief that they were not essential or economical. Replies to a question on the number of sprays applied in 1922 were received from 145 growers. Of these only 8 applied the full program of 7 applications as recommended in the spray calendar for that year. The average grower applied 4 or 5 sprays, while 7 sprays were found necessary for satisfactory results in the spraying experiments.

About 40 per cent of the growers used spray guns in 1922, 25 per cent used rods, and 35 per cent used the two in combination. It is true that satisfactory results can be obtained with the gun with proper handling but it is more often mishandled than the rod and the speed spraying and long range work that often accompany the use of the gun are probably responsible for much inadequate covering and lack of protection.

Summary

The discharge of ascospores of the scab fungus from fallen, overwintered leaves of apple occurs during or immediately following rainfall and these spores cause the first infections of leaves, blossoms and fruits under favorable weather conditions. Weather conditions are of major importance in determining the severity of scab infection; the most important weather factors being rainfall and high atmospheric humidity.

Infection may or may not result from ascospore discharges, depending on the type of weather which follows immediately after the discharge and the stage of development of the apple leaves and fruit. Conditions are favorable for infection when the weather is muggy with little drying of foliage and fruit for some hours following discharge. They are unfavorable, when discharge is followed by a marked drop in humidity with quick drying of the parts of the trees.

The period of ascospore discharge at Winchester in 1922 extended from April 18 to June 12, a total of 56 days, and ascospores were discharged on 16 separate days during this period. There were 13 ascospore discharges in 1923 covering a period of 94 days, from April 28 to July 30. The heaviest discharges in both years occurred during the middle part of May.

Ascospore discharges which occur after the first of June are of less importance, as a rule, than those which occur prior to this date. The most important discharges are those which occur during the latter part of April and the month of May, particularly those which occur just before, during, and shortly after the blooming period. This is the period of most rapid development of leaves and of greatest susceptibility to leaf and fruit infection.

A severe epidemic of scab occurred in 1922 as a result of the wet season which was unusually favorable for ascospore discharge and infection. The reverse was true of 1923; conditions during the dry, early season were unfavorable and scab infection was so slight as to be of almost no commercial importance. The maximum percentage of scabby apples found on unsprayed trees in 1923 was only 7.6 as compared with 98.4 per cent in 1922.

A very satisfactory control of scab was obtained on the susceptible varieties, Winesap, Rome, and Stayman, in the epidemic year of 1922 with standard spray materials, lime-sulfur and Bordeaux mixture, applied according to the Virginia spray calendar. The percentages of scabby apples in the four plats which received the full schedule of seven applications were: 4.9, 7.5, 8.1, and 12.5 while the comparable percentages from unsprayed trees of the same varieties were: 76.0, 97.3, 98.4, and 97.0.

The most important scab sprays in 1922 were the pink, calyx, and the two-weeks. Of these the pink was of greatest importance, calculated value 50 per cent, the calyx was second in importance, calculated value 25 per cent, and the two-weeks was third in importance, calculated value 15 per cent. The delayed dormant and five-weeks applications were of but slight importance; their combined values being 10 per cent. The ten-weeks and August sprays were of no value in scab control.

The sprays which were of slight or no value in scab control were of value in the control of other diseases or of insect pests and the complete schedule of seven applications produced the highest percentages of blemish-free apples.

No conclusions as to the relative values of the different spray applications in scab control can be drawn for 1923 owing to the very

slight infection. The full program of 7 applications again produced the highest percentages of blemish-free apples and it is evident that the omission of sprays in years of little scab may be accompanied by serious injuries from other diseases or insect pests.

Orchard and cull pile surveys indicate that scab is the most important apple disease of the Winchester section in wet seasons. Approximately 31 per cent of the culls in 1922 were caused by scab. A high percentage of the cull apples in both 1922 and 1923 was caused by diseases and insects that are preventable by spraying. Failure to secure adequate control of diseases and insects was found in general to be due to an insufficient number of spray applications; to improper timing of the sprays applied, and to lack of thoroughness in the covering of foliage and fruit with spray materials. These are correlated with and occasioned by the lack of adequate spraying equipment. Many of the orchards in this section are not equipped with enough spray machinery to permit of thorough covering during the time limits for most effective results.